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RESEARCH REPORT

APPLICABILITY OF LASERS TO CLOSE AIR SUPPORT FOR
THE UNITED STATES MARINE CORPS

LIEUTENANT COLONEL JERALD R. AGENBROAD

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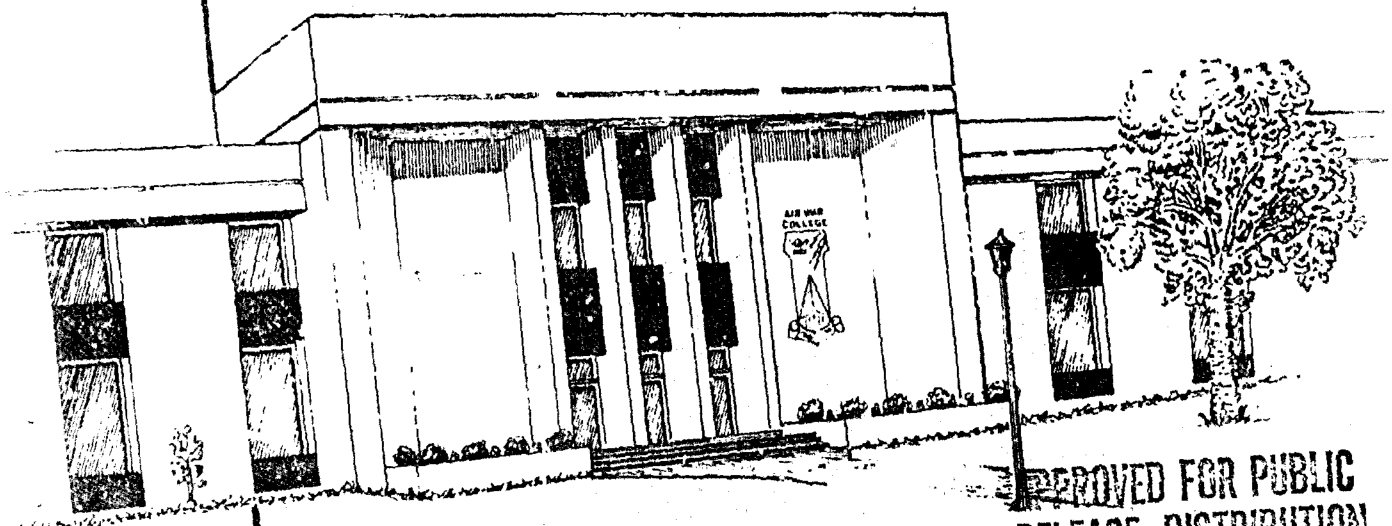

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APPLICABILITY OF LASERS TO CLOSE AIR SUPPORT FOR THE UNITED STATES MARINE CORPS

by

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A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH

REQUIREMENT

Research Advisor: Lieutenant Colonel Rodney M. Payne

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AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: Applicability of LASERS to the Conduct of Close Air Support for the United States Marine Corps

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A brief discussion of the rationale for having an aviation branch in the USMC precedes a more detailed background on the concerns and objectives of Close Air Support (CAS). This leads to the requirement for increasing the accuracy of the weapons in the CAS arsenal; hence, the exploration of laser designators, laser receivers, and laser guided weapons for employment in the conduct of CAS. The Marine philosophy for fire support coordination and the doctrinal prerequisites for the conduct of effective CAS are examined to assess the degree to which they have been impacted by the introduction of lasers. A description of the laser equipment in the Marine inventory is presented with an analysis of some operational considerations which derive from the characteristics of that equipment and laser energy in general. Following that background, two potential applications for lasers in CAS are analyzed: The use of laser technology for the terminal guidance of weapons, and the use of laser equipment as an augmentation to the communication process necessary for the conduct of CAS. The author presents his recommendations for using lasers in CAS and suggests a course for the USMC to follow in the future. (SDW/JES)

BIOGRAPHICAL SKETCH

Lieutenant Colonel Jerald R. Agenbroad (M.A.B.A., Webster University) has been actively involved in developing and teaching CAS tactics within the Marine Corps since his assignment as the Fixed Wing Branch Head, Marine Aviation Weapons and Tactics Squadron in 1978. It was during that assignment that Lieutenant Colonel Agenbroad extensively studied the applications for lasers in the prosecution of Offensive Air Support. A naval aviator, he entered the USMC in 1967, received his wings in 1968 and was immediately assigned to an A-4 squadron. His active flying assignments have included numerous assignments in the CONUS, one tour in Vietnam, and two tours in Japan. Eighteen years active duty as an attack pilot culminated in two years as the Commanding Officer of the Marine A-4 training squadron from 1984 to 1986. His personal decorations include the Purple Heart, Defense Meritorius Service Medal, Meritorius Service Medal, and Air Medal (numeral 5). Lieutenant Colonel Agenbroad is a graduate of the Air War College, class of 1988.

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CHAPTER I

BACKGROUND

1. Introduction. The United States Marine Corps (USMC) first successfully employed air delivered ordnance in support of friendly troops in contact with enemy troops in Nicaragua in 1928. (14:37) Thus began the art of Close Air Support (CAS) within the USMC and the continuing effort to improve the ability to coordinate, control, and increase the first round accuracy and lethality of this potent source of fire support. As stated in the Marine Corps Gazette, "the requirement for delivery accuracy in CAS stems from two criteria: The need to hit the target, and the need to miss friendly forces". (7:32) Those two parallel requirements provide the framework for the USMC definition of CAS and are the parameters around which the doctrinal prerequisites for the conduct of CAS have evolved. Those doctrinal prerequisites are: air superiority, suppression of enemy air defenses (SEAD), target marking, favorable weather, flexible control, prompt response, and aircrew and terminal controller proficiency. (13:101) They will each be discussed in detail later, but it is germane to mention here that the attainment of these prerequisites, or alternatively, enabling the conduct of effective CAS in the absence of one or more of these prerequisites, has been a significant driving force behind the

USMC search for new weapons and technology. Consider, for example, a weapon which, through technological advances, has a dramatically expanded delivery envelope and increased accuracy attained through terminal guidance. The "aircrew proficiency" prerequisite for delivering that weapon is easier to accomplish because successful delivery is not as difficult and will not require as much practice. However, CAS is but one aspect of Marine aviation, and before focusing on that narrow, albeit important, category of the support functions that air assets provide the ground commander, a broader look at Marine aviation is appropriate.

2. Marine Air Support. The expeditionary nature of Marine forces and the requirement for them to enter a combat environment by force, starting from a "zero" base, particularly while conducting the amphibious operations critical to the "...seizure or defense of advanced naval bases and the conduct of such land operations as may be essential to the prosecution of a Naval campaign...", the primary mission of the Marine Corps, imposes unique needs for mobility and firepower. (13:2) The mobility and flexibility of tactical air power are well suited to meet those needs and are vital elements in the Marine capability to accomplish that primary mission. The evolution of air support in the Marine Corps has continued through the intervening years since the Marine campaign in Nicaragua and has resulted in the

formalized structure of Marine aviation today which fulfills the following six critical functions in meeting the requirements of the Marine Corps: air reconnaissance, antiair warfare (AAW), assault support, offensive air support (OAS), electronic warfare, and control of aircraft and missiles. Each of these functions contributes significantly to the overall success of USMC forces in combat, but OAS is the function most directly concerned with "putting ordnance on the enemy" and is, therefore, arguably of most immediate concern to the ground commander. CAS is a subset of OAS and is the function within which the thesis of this paper is housed. (13:99-100)

3. Requirement for CAS. Those operations conducted within the function of OAS "...are in close proximity to friendly forces and which require detailed integration of each air mission with the fire and movement of those forces..." are defined within the USMC as CAS. (13:7) To elaborate briefly, CAS includes all of the OAS which takes place on the friendly side of the fire support coordination line (FSCL); "...a line established by the appropriate ground commander to ensure coordination of fire not under his control, but which may affect current tactical operations." (5:3-3) The ground commander's requirement to coordinate all fire support behind the FSCL is driven by the necessity for him to have freedom to maneuver his forces in that area without the fear of being engaged by friendly fire; hence,

the FSCL and the requirement for each CAS mission to be individually coordinated with the ground forces. While the force structure of the USMC is accurately described in the words of Colonel J. C. Naviaux, "the Marine Corps is a 'light infantry' force and therefore, heavily dependent on CAS for fire support" (14:37), CAS is not the only fire support asset at the ground commander's disposal. The Marine philosophy for fire support coordination and employment will be discussed in more detail later, but suffice it to state here that CAS assets will be employed only if the other available fire support assets have neither the range nor the firepower to inflict the desired degree of damage on the target. (6:1-18) A dramatic development in the constant search to maximize the effectiveness of CAS occurred in the latter days of the Vietnam conflict when terminal guidance of air delivered weapons was successfully accomplished yielding previously unheard of accuracy in a tactical situation. (8:28) This revolutionary improvement in accuracy promised great gains in the two requirements that CAS is expected to fill: to hit the enemy, and miss the friendlies.

4. Lasers introduced. The active U.S. combat operations in Vietnam were drawing to a close when a new application of laser technology was successfully demonstrated on the battlefield. First generation laser guided bombs (LGB) were used to destroy several targets with previously unthinkably minimal commitment of

assets and associated losses. According to then Deputy Secretary of Defense Packard,"...to destroy six types of individual targets with 500 pound bombs, up to 1000 sorties were required at a cost of $15 million. With the "right" weapons, these targets could be destroyed by 20 sorties at a cost of only $600 thousand." (21:18) The "right" weapon to which he referred was the Paveway I MK84 2000# General Purpose (GP) bomb. His point was clearly demonstrated on 13 May 1972 when, on the first attempt with LGB's, the Thanh Hoa bridge on the railroad running south out of Hanoi was destroyed. Over the previous four years, hundreds of sorties had been flown utilizing "dumb" bombs, and 10 aircraft had been lost in the unsuccessful efforts to destroy that one bridge. (8:28-31) An equally impressive statement was made about this new weapon's effectiveness against more mobile tactical targets when, "One mission near Quang Tri netted four tanks destroyed in five minutes using five bombs." (8:33) That impressive demonstration of accuracy and lethality began a love affair between the USMC and laser equipment and weapons which is continuing today.

The two potential applications for lasers in the conduct of CAS are: terminal guidance of laser guided weapons, as was demonstrated in Vietnam; and as a means of facilitating the difficult communication process between the forward air controller (FAC) and the CAS delivery pilot. The context of that "communication process" includes identifying the target for the

delivery pilot. Both of these applications will be addressed in detail later in this paper.

5. Purpose. This paper will: discuss briefly the Marine philosophy and methodology for fire support coordination; examine the capabilities of the laser designators, receivers, and laser guided weapons the USMC has acquired for employment in the conduct of CAS; analyze the doctrinal prerequisites for the conduct of CAS in terms of how their attainment may be enhanced, or degraded, by laser equipment and laser guided weapons; and finally, consider the two potential roles for lasers in CAS to determine whether they have an overall positive or negative effect on the attainment of the prerequisites for CAS and whether there are realistically effective roles for lasers in the conduct of CAS.

The discussion in this paper will be limited to the consideration of laser applicability to CAS conducted by high performance, fixed wing aircraft. There are other laser guided munitions available in the arsenal of supporting arms which are delivered by helicopters, artillery, and naval gunfire. The laser designators used in the employment of those weapons are the same as the laser designators used for guiding laser guided munitions delivered from high performance aircraft, so many of the comments regarding designation apply in both cases. The

helicopter, artillery, and naval gunfire delivered weapons are, however, significantly different and will not be addressed in this paper.

CHAPTER II

FIRE SUPPORT COORDINATION

1. General. An understanding of the philosophy underlying USMC fire support employment is necessary for a complete understanding of CAS and the role that laser equipment and laser guided weapons can play in the conduct of CAS.

2. Fire support coordination philosophy. The array of potential targets for CAS is essentially the same as the list of targets which a ground commander compiles in preparation for, and in the conduct of, a combat operation. Many times, in mid to high intensity combat, the number of potential targets exceed the capabilities of the fire support assets available to the ground commander. (5:7-4) Therefore, there must be a plan for deciding which targets will be engaged and by what fire support system. The fire support plan for a given operation is covered by the commander's guidance and may vary somewhat from operation to operation, but the underlying USMC philosophy for making the determination of which means of fire support to bring to bear on a given target is described by the following principles: (The italics are provided in the following lists by this author to highlight those principles, factors, and objectives which are germane to this paper.)

FIRE SUPPORT PRINCIPLES

-*Consider the use of all fire support available.*

-Furnish the type of fire support requested.

-Provide rapid coordination.

-Assign fire mission to the agency capable of delivering the most effective fire.

-*Use the lowest echelon capable of furnishing effective support.*

-Ensure a continuing flow of target information.

-Provide safeguards to friendly troops, vessels, aircraft, and installations.

-Avoid unnecessary duplication.

-Coordinate airspace. (6:1-18)

In implementing that philosophy, the following factors are considered in the actual matching of a specific weapon system with a specific target:

FIRE SUPPORT FACTORS

-Tactical organization

-*Type of weapons and ammunition available*

-*Accuracyf of supporting arms systems*

-Mobility and range

-Ability to mass fires

-*Rapidity of execution of fire support*

-Vulnerability and continuity of action (6:1-11)

Once these principles and factors have been considered, then the appropriate supporting arm is tasked to provide fire support which will then be integrated with the maneuver of the ground

combat element by accomplishing one of the following general objectives:

FIRE SUPPORT OBJECTIVES

-*Suppressing direct fires, indirect fires, and enemy air defenses.*

-Covering movements and obscuring the vision of enemy observers and gunners.

-Enhancing economy of force actions.

-Sealing off enemy counterattacks.

-Maximizing firepower effects for the longest time.

-*Destroying the enemy's combined arms team's integrity. (6:1-11)*

The result of that philosophy being applied to those factors for the accomplishment of the listed objectives is that the ground commander will engage the enemy target with the weapon over which he has the most direct control and which is also capable of inflicting the desired level of damage or destruction on the target. Those sources of fire support, in a general order of decreasing direct control by the ground commander are: weapons integral to the ground combat element (not technically fire support assets); direct support artillery/ naval gunfire; general support artillery/ naval gunfire; and at the upper end of the scale, CAS.

The principles, factors and objectives listed above for fire support are reflected in the doctrinal prerequisites for effective CAS and have been directly involved in the effort to

incorporate lasers into the conduct of CAS. For example, the fire support factors "type of weapons and ammunition available", and "accuracy of supporting arms" are reflected in the search for increased accuracy which has lead to the consideration of laser guided weapons for CAS (and the other supporting arms). The type of potential target that drove the search for the degree of accuracy provided by terminal guidance will now be considered.

3. Potential CAS targets for laser guided weapons. The tank is one of the most feared ground based conventional weapons on the battlefield today because of its firepower, mobility, and relative invulnerability to attack. It is logically, therefore, very high on the priority list for elimination. Tanks have on occasion, however, been moved down the priority list of targets, not because they are less of a threat, but because the weapons available did not have the combination of firepower and accuracy to inflict the desired degree of damage. (5:7-6) As the tank has evolved into a more "hardened" state through increasingly effective armor, the catalogue of ordnance which can "kill" it has continued to decrease. (6:73) Specialized shaped warheads have been developed to provide the increased penetration necessary to get through a tank's armor and into its vital parts and crew. The directed nature of the explosive power of these warheads have decreased their utility against "softer" targets. Instead of creating a large, non-concentrated area of blast and

fragmentation damage, as is present when a general purpose bomb explodes, the shaped warhead creates a very concentrated, highly directional blast. Therefore, while extremely destructive within the focused blast, it is relatively non-lethal in proximity to the detonation but outside of the area of directed blast. This increases the accuracy requirements for such a warhead. No longer is a "near miss" effective. In order for the shaped warhead to work, it has to be a direct hit. (26:--)

The warhead of the Paveway series LGB is an unmodified GP bomb, and retains the area destruction characteristics of the basic bomb while gaining the accuracy of a terminally guided weapon. Even the non-specialized warhead of the Paveway LGB has a tank killing capability which was successfully demonstrated on the battlefields of Vietnam. (8:33) The Laser Maverick, a Marine developed laser guided missile which will be discussed in detail later, on the other hand, does have a specialized armor piercing warhead. The result of its special warhead is that the Laser Maverick should be even more lethal to a tank, given a hit. As will be pointed out later, however, there are severe impediments to successfully employing laser guided weapons delivered from high performance fixed wing aircraft on the modern battlefield facing our forces today, particularly in the area where CAS will be conducted.

More lucrative and vulnerable targets for the massive firepower associated with CAS are the mounted and foot infantry

accompanying the tanks, as well as the command and control, and other support equipment. These targets are not as hardened as tanks and can be killed, or rendered ineffective by the nondirectional explosion and fragments of a general purpose bomb, rocket, cluster bomb unit, or napalm. The ground commander also has many other "non-laser" alternatives available to him for engaging the armor threat, some of which will be considered now.

4. Ground based alternatives to CAS. In the area where CAS will be conducted, the ground commander has at his disposal numerous ground based weapon systems with the requisite warhead and accuracy to destroy tanks. The USMC "defense in depth" concept provides a lethal alternative for engaging enemy tanks. Under this concept, the heavy antitank weapon (HAW) is the TOW guided missile with an effective range out to 3750 meters. The medium antitank weapon (MAW) is Dragon (improved warhead) and is effective to 1000 meters, and the light antitank weapon (LAW), the AT-4, is good out to 200 meters. The HAW and MAW can kill or immobilize any known enemy armored vehicle and the LAW can immobilize any known armor on the battlefield (6:3-10,11). Given the desire to engage a target with the weapon available at the lowest echelon which has the capability to inflict the desired degree of damage, the weapons within the defense-in-depth concept should be the preferred choice over CAS for attacking tanks in contact with friendly forces. This is not to say that CAS is

unnecessary. The massive firepower it provides is still vital to engage the targets which exceed the firepower capability of the other supporting arms, but it should be used against targets which will maximize its effectiveness.

We will now consider lasers in general and, specifically, the laser designators, laser receivers, and laser guided weapons available to the ground commander for use in CAS within the context of this paper.

CHAPTER III

LASER DESIGNATORS, RECEIVERS, AND GUIDED WEAPONS

1. General. The USMC has a number of systems and weapons which are capable of either emitting, receiving, and/or being guided by laser energy. All of this equipment lies within one of the following three categories: laser designators; laser receivers, usually in aircraft; and, precision guided munitions relying on laser energy for guidance. The various systems will be described in the following paragraphs. Even though many of the technical and operational specifics of these systems are classified, this description will be limited to that information available in open sources since it is felt that the information available in those sources is comprehensive and specific enough to fulfill the purposes of this discussion. Before discussing specific laser systems, however, a brief discussion of laser energy is necessary to facilitate an understanding of the characteristics which make laser energy suitable for designation and guidance, and to give an appreciation for the effects that atmospheric and environmental conditions can have on laser energy.

2. Laser energy. The acronym "laser" comes from light amplification by stimulated emission of radiation. The energy generating medium used in the USMC laser designators is

neodymium:yttrium aluminum garnet (ND:YAG) which creates a beam of laser energy that is near visible light on the wavelength scale, but is not visible. Because it is near visible light in wavelength, its transmission characteristics are similar to those of visible light. In other words, if conditions are such that light will penetrate, then generally, laser energy from a ND:YAG source will penetrate, and vice versa. (12:74)

Military laser designators are "pulsed", thereby emitting discrete pulses of laser energy invisible to the naked eye. Some of the characteristics (primarily pulse repetition frequency) of those pulses of energy are controllable, and through that method, the laser designator can emit "coded" laser energy. That uniquely coded laser energy can then be unambiguously identified by a laser receiver or a laser guided weapon set to "see" only laser energy with that unique coding. Additionally, the laser energy is emitted in a very concentrated beam with minimal divergence. The resultant cross section size of a laser "spot" of energy remains very small at extensive ranges from the designator. For example, the MULE, a designator that will be discussed later, emits a beam of laser energy with a cross section of only 27 inches at a range of 3000 meters from the designator. That minimal divergent characteristic and the coding of the pulses remain essentially unaltered during reflection, providing a coherent, concentrated, and coded beam of reflected laser energy for a laser receiver to "see", or for a laser guided

weapon to "home" on. (10:2-2,2-3)

Atmospheric conditions which impede visual light will have a similar deleterious effect on the transmission of laser energy. Clouds, fog, and visible precipitation will impede the transmission of laser energy and block the view of laser guided munitions and laser seekers to about the same extent that visual line-of-sight is impeded. An even more serious impediment to laser energy transmission and reception on the battle field is smoke. Not only does smoke attenuate the transmission of laser energy, it can, to some degree, scatter it, resulting in the possible creation of false "targets". The "pulsing" of laser energy helps, but does not completely overcome this problem. Darkness has no deleterious effect on the transmission or reception of laser energy, as long as the previously mentioned atmospheric conditions are not present. (10:6-2,6-3,6-4)

A final note about the application of laser energy in this context is that the energy must be directed at, and reflected off of the desired target. The physics of reflection and the varied shapes and reflectivity of potential targets dictate that the laser receiver, or laser guided weapon, must "look" from within a cone 45 degrees, or less, either side of the designator-to-target line. This requirement imposes restrictions on the selection of attack heading for the CAS delivery aircraft that will be addressed later. (10:2-4)

With that general description of laser energy characteris-

tics in mind, we will now consider the systems the USMC has available which emit, receive, or guide on laser energy.

3. Designators. The USMC has invested in three laser designators, two airborne and one ground portable, which are all in the active inventory. The two airborne designators are incorporated in the AN/AAS-37 system carried by the OV-10D aircraft, and the Target Recognition and Attack Multisensor (TRAM) turret carried on the A-6E aircraft. The ground based designator is the Modular Universal Laser Equipment (MULE). All three designators are selectively codable and are compatible with all of the receivers and laser guided munitions available to the USMC. (10:--)

a. AN/AAS-37 Designator. This designator is incorporated in the AN/AAS-37 pod, located on the underside of the nose of the OV-10D aircraft, and has the capability to emit fully coded laser energy for the dual purpose of target designation and range finding. The AN/AAS-37 pod also incorporates a gimbal mounted, multi-mode, pilot selectable, infrared (IR) or visual automatic target tracking system to which the laser designator is slaved. The IR mode of operation provides the capability to acquire, track, and designate targets in daytime or nighttime conditions in relatively clear atmospheric conditions. (10:2-12,A-8)

b. TRAM Designator. The laser designator incorporated in the TRAM turret carried on the underside of the A-6E aircraft is fully codable and is slaved to an IR sensor, also located in the TRAM turret. The TRAM system, working in conjunction with the A-6E on board air-to-ground radar, is effective for navigation and weapons delivery. This array of multi-sensor capabilities make the TRAM equipped A-6E a versatile day, night, and all-weather bomber. It is an excellent platform for delivery of laser guided weapons and the TRAM laser designator can be used for self designating for the guidance of its own LGB's, or to designate for those laser guided weapons delivered from another aircraft. (4:47)

c. MULE. The MULE, weighing 38 pounds and consisting of four modules, is divided into a two man load for tactical transport. It is fully codable and is compatible with all the laser receivers and laser guided weapons available for Marine use (10:2-8). The four modules comprising the MULE are: the laser designator/ rangefinder; the stabilized tracking tripod module (provides a steady base); the north finding module which has the capability to measure true north and determine grid north; and, a night vision goggle sighting device for use in acquiring, ranging, and designating targets at night in relatively clear atmospheric conditions. The north finding module is an important feature because the maps used by the ground Marines are grid maps

oriented to grid north while those used by aircrew are oriented to true or magnetic north. With the integral capability of the north finding module to display both grid north and true north, the controller no longer is required to do the mathematical computations necessary to make the conversion from grid to true to magnetic north, and vice versa. This becomes especially important in controlling an A-6E Radar Beacon with Forward Air Controller (RABFAC) mission. In this type mission, the controller positions a radar beacon which can be located and identified by the A-6E radar. Then he provides the target position relative to that radar beacon in terms of range and azimuth (relative to magnetic north) to the crew of the A-6E. This information is then fed into the aircraft computer and is used as the reference for weapon delivery. The MULE significantly increases the effectiveness of RABFAC by providing more accurate beacon-to-target range and heading than the "controller estimates" which were previously used. (10:7-23)

The ease of transport of the MULE and its capability to range and designate targets make it an extremely versatile device for the ground commander to use in the control of his supporting arms. The normal location of the MULE is with the FAC team.

4. Aircraft receivers. The laser receivers installed in Marine aircraft are fully codable and provide the delivery aircrew the ability to identify the location of a spot of coded laser energy.

Once the receiver senses laser energy that matches the preset code, the location of that laser energy is depicted via electronic symbology on the head's up display (HUD), radar scope, or pilot's television screen. This type of laser receiver is generally referred to as a laser spot tracker (LST). The LST enables a FAC to select and specifically depict, with a laser designator, the exact location of a target, in near real time, to a CAS delivery aircrew.

The aircraft incorporating LST's are the A-4M, the AV-8B, and the F-18. The TRAM equipped A-6E depicts laser energy on the radar scope. The OV-10D laser system will both depict the location of the laser energy on the pilot's TV scope and provide laser ranging. (6:--)

5. Laser Guided Weapons. There are two types of laser guided weapons which can be carried and delivered by Marine fixed wing aircraft. The first, the Paveway series LGB, consists of a standard MK-80 series GP bomb with a special kit attached to provide the laser guidance capability. There are kits for the 500#, 1000#, and 2000# MK-80 series GP bomb. The second type of weapon is a laser guided missile, the Laser Maverick. A requirement common to both types of weapons is that in order to be effective as terminally guided weapons, they must have time to correct their trajectory to the target after they have "acquired" the designated target. In other words, they must acquire the

spot of reflected laser energy long enough prior to impact to "home" on the target. The specific minimum guidance time recommended is classified, but suffice it to say that the more time the weapon has to react, the more apt it is to get a good hit. (8:31) The weapon's ability to react is limited by the aerodynamic characteristics of the basic weapon, its fins, and the canards which provide the steering forces to the weapon. The Paveway LGB is not available in a "retarded" configuration, so the minimum safe delivery parameters are similar to those for a normal unretarded GP bomb.

a. LGB's. The Paveway LGB is a particularly useful and adaptable weapon because it's warhead component is the basic MK-80 series bomb which should be in plentiful supply during any significant conflict involving United States military forces. Although the Paveway I kits, the initial guidance units employed in Vietnam, are still in the inventory, their numbers are insignificant and they are no longer in production. Therefore, only the second generation version, the Paveway II, will be considered.

The major improvements of the Paveway II over the Paveway I are: full codability instead of the limited codability of the Paveway I, and dramatically improved aerodyramic characteristics which provide an expanded employment envelope. An attractive advantage the Paveway concept provides over Laser Maverick is that

the terminal guidance capability of the weapon is completely self contained, so any aircraft capable of carrying and delivering a MK-80 series bomb is capable of delivering a Paveway weapon. This means that there is no bomb to aircraft interface, other than that required for normal electrical fuzing. The Paveway weapon is dropped "dumb" and doesn't "come to life" in a "guided" mode until after release from the aircraft. This lack of a weapon-to-aircraft interface for the guidance system eliminates many potential reliability problems associated with aircraft wiring and electrical systems. A second consideration, and possible drawback, caused by the lack of bomb to aircraft interface is that if the pilot needs to see where the laser energy is emanating from to ensure that the bomb will guide on the "correct" target, as is usually the case in CAS, a LST will have to be incorporated in his aircraft. Then, even with a LST indicating the presence and location of the laser spot, there is no guarantee that the LGB will "see" it after release. This detracts from the safety of the friendly ground troops in the proximity of the target.

Significantly, unlike the Laser Maverick, the Paveway II LGB has no safety device to either alter its flight path, or interrupt its arming sequence if the laser spot is not acquired. It will explode in accordance with the fuzing function, whether or not laser guidance has taken place. Another characteristic of Paveway II LGB's germane to the CAS environment is that in in-

stances of guidance failures or malfunctions, the common tendency is for the weapon to impact short. (7:31) This becomes more important when you consider, as previously discussed, that the weapon must be delivered within a cone plus or minus 45 degrees of the designator-to-target line. The resultant weapon path after release will, therefore, be more or less "six o'clock to twelve o'clock" relative to the designator position, thereby making "short hits" more critical.

b. Laser Maverick. The Laser Maverick is a USMC adaptation of the IR/TV Maverick missile developed by the United States Air Force. The modifications for the adaptation included the development of an optional larger, shaped warhead, and the laser guidance capability of the weapon. The Laser Maverick is completely codable and is compatible with all of the Marine laser designators.

The Laser Maverick "interfaces" with the launch aircraft through a series of electrical cables and provides the aircrew with a display on the HUD of the location of the laser energy it "sees", similar to the function of an LST. This characteristic makes it a "lock on before launch" weapon, thereby providing enhanced safety to the friendly ground troops because the delivery pilot knows that the missile is locked onto a properly coded spot of laser energy prior to weapon release. He may also be able to correlate the location of that spot visually, if conditions per-

mit. Laser Maverick has an additional feature incorporated that causes it to fly long if it "loses" the laser spot or senses another malfunction between launch and impact. This overcomes the LGB tendency to impact short, thereby providing additional safety to friendly troops and some degree of control of the weapon to the ground commander, especially if the target designation is being provided by his MULE.

The penalty associated with the "lock on before launch" characteristic is that it increases the time that the designation must be successfully accomplished. Instead of requiring laser designation only during the terminal phase of flight, effective laser designation must be accomplished continuously from the prelaunch acquisition phase, until weapon impact. Otherwise, the Laser Maverick will sense a "loss" of the laser spot and it will "pitch up" and fly long. (1:39,40)

6. <u>The need for lasers</u>. A major reason that the systems described above have been acquired by the USMC is to enhance the ability to more effectively conduct CAS. To see how those systems have the potential to do that, we will now look briefly at the doctrinal prerequisites for the conduct of effective CAS.

CHAPTER FOUR

DOCTRINAL PREREQUISITES FOR CAS

1. General. The continual effort to improve the ability to achieve the two objective of CAS: to destroy enemy targets, and leave friendly forces unharmed, has led to the development of several prerequisites for the conduct of effective CAS. Both the USMC ground and air commanders have agreed to those prerequisites and have institutionalized them in doctrine. Those prerequisites have remained more or less unchanged for many years, but changing technology and tactics, both of the threat and friendly forces, have forced modification of the meaning and methods of attainment of those prerequisites for the conduct of effective CAS. For example, the RABFAC capability of the A-6E aircraft has put a significantly new interpretation on the requirement for "favorable weather", since the delivery aircrew employing that tactic can positively identify the location of friendly forces (the radar beacon) and locate the target (relative to the radar beacon) in all weather conditions using the onboard radar. Similarly, some of the other prerequisites have received new emphasis and methods of attainment through the marvels of modern science.

The doctrinal prerequisites for the conduct of effective CAS are: air superiority, suppression of enemy air defenses (SEAD),

target marking, favorable weather, flexible control, prompt response, and aircrew and terminal controller proficiency. These prerequisites will be dealt with in the following paragraphs only as they pertain to, or are affected by laser equipment and laser guided weapons. {13:--}

2. Air Superiority. This prerequisite for CAS remains essentially unchanged by the laser's introduction onto the CAS battlefield.

3. SEAD. This prerequisite for CAS remains essentially unchanged by the laser's introduction onto the CAS battlefield.

4. Target Marking. This is the prerequisite which is most significantly affected by the introduction of lasers. The requirement for the target to be marked implies that the CAS delivery pilot must positively identify the target before delivering ordnance against it. {13:101}

The first of two ways this prerequisite can be impacted is by using lasers to mark the target for a laser guided weapon; thereby relying on that weapon's terminal guidance capability to discern and guide to the target. This can be done either simultaneous with the designation of the target to the aircrew as described below, or it can be done independently. The problem with designating the target for a laser guided weapon without the

pilot having some indication that the weapon is "seeing" the target in a CAS environment is that the pilot can't ensure that the laser guided weapon will guide on the correct target, thereby increasing the hazard to friendly troops. Another disadvantage of employing laser guided weapons is the relatively long periods of designation required to maximize the terminal guidance. As will be developed more fully later, the difficulty of designation and the risk to the designator operator increase as the duration of designation increases.

The second way this prerequisite is impacted is through the ability of the FAC to unambiguously "point out" the target to the attack aircrew without relying on two way communication by designating the target with a coded beam of laser energy. That reflected beam is then received by a LST in an appropriately equipped aircraft and the target location is depicted "real time" to the pilot on his HUD. Then he can engage the target with any of a variety of normal unguided weapons. This solves what an F-105 pilot with 145 missions over North Vietnam described as the most difficult problem facing an attack pilot when he said, "simply finding the target during the daytime is the most acute problem" {2:102}.

5. Favorable weather. This prerequisite is essentially unchanged since, as discussed earlier, the laser energy used by

Marine designators has transmission characteristics similar to visible light. In other words, if you can see it, you can "lase" it, and vice versa. The single major enhancement to the favorable weather prerequisite is that in relatively clear darkness, the ability to designate a target location with a laser designator dramatically enhances the capability to conduct night CAS by enabling the delivery aircrew to locate and unambiguously identify targets with the LST that would otherwise be difficult, or impossible to mark.

6. Flexible Control. This prerequisite is clearly enhanced by lasers. Laser equipment provides a means of communicating between the controller and the CAS delivery pilot without "talking". Discreetly coded designators and similarly coded receivers allow the presence of discreetly coded laser energy to be used to convey a variety of precoordinated information. i.e., target location, clearance to fire, friendly position, etc.; thereby, reducing the reliance on radios for the conduct of CAS.

7. Prompt Response. This prerequisite is both positively and negatively impacted by the use of lasers. According to a Department of Defense study of CAS conducted in 1972, "the first fifteen to twenty five minutes of combat are critical to the outcome of any engagement." (15:23) It is important to employ the massive firepower of CAS during that period where it can do

the most good. The real meaning of response time is the time between initiation of the request for a CAS mission and the time that requested mission delivers its ordnance on the target. (15:23) In that regard, lasers have the capability to reduce the response time by reducing the time necessary to describe the target and "talk the eyes" of the pilot onto the target. With appropriately coded laser designators and receivers, that historically time consuming task can be accomplished by lasing the target with appropriately coded energy so the target location will be depicted instantly to the pilot on the LST. The response time will be somewhat adversely affected, however, because of the increased coordination necessary to ensure that the designator and the aircraft system, and/or terminally guided weapon, are on the same code. This minor increase in response time will be more than offset by the time savings realized in the target identification process.

8. Aircrew and Controller Proficiency. Lasers have impacted this prerequisite in two areas: laser designator training, and weapon delivery aircrew training. Any new system or weapon requires training and practice to effectively employ it. The additional training requirements for the aircrew using the LST and delivering the laser guided weapons are much less than the additional training requirements for the designator operators. The presentation and symbology associated with laser systems that

the aircrew has to master are very similar to, and react much like many of the other presentations and symbology they are already trained to deal with. The tactics used to deliver laser guided weapons, similarly, are very much like the tactics used to deliver other weapons already in the training repertoire.

The designation task, on the other hand, is a completely new and extremely difficult task to accomplish. For operational reasons beyond the classification of this paper, the technical aspects of successfully designating a target are complex and difficult to master, levying a significantly increased requirement for training and practice to attain and maintain an acceptable level of proficiency in the art of laser designating. The factors unique to lasers that must be mastered include: an understanding of the operational limitations of the laser guided weapons; an understanding of laser energy and how the laser beam reacts to various atmospheric conditions; an understanding of target reflectivity and shape; and, significant additional control and communications concerns related to the coordination of the details relating to the actual designation. (10:--).

With the preceeding discussion in mind, we will now consider the potential for lasers to be successfully employed to facilitate the conduct of effective CAS.

CHAPTER V

LASER APPLICATIONS TO CAS

1. General. The beamlike characteristics and the unique coding of laser designators, receivers, and laser guided weapons offer two potential applications for lasers to enhance the USMC capability to conduct more effectve CAS. The first application, terminal guidance, gives the ground commander the ability to unambiguously designate a target to a terminally guided weapon. The accuracy revolution resulting from the use of laser guided munitions has produced dramatic results in the search for "one bomb, one kill". That increased accuracy should encourage the ground commander to use CAS ever closer to his own position with both a high expectation that the target will be neutralized, and just as important, that the ordnance will not impact on his own position. The other application for lasers in CAS, the use of lasers for communication of vital information such as target location to the CAS aircrew has equal potential to be helpful in conducting more effective CAS. This second application stops short of employing terminal guidance and instead, relies on the skill of the aircrew and the accuracy of the aircraft weapon system to deliver unguided "dumb" ordnance on the designated target. This chapter will consider those two applications of lasers to CAS to determine if either, or both, applications can

actually make any *significant* contribution to the conduct of effective CAS.

2. Terminally guided weapons. Major General J. C. Maxwell, following the Vietnam experience with laser guided bombs, made the following observation while expressing his pleasure at the excellent results: "Paveway I bombs can come close, but there is a need for increased accuracy for things like tanks and bridge revetments where a "direct hit" is required for a kill." (24:27) Arguably, a properly functioning laser guided weapon on a properly designated tank will have the requisite accuracy to achieve a "kill" and, General Maxwell's remarks notwithstanding, tanks were engaged by laser guided bombs in Vietnam with a high degree of success. (8:13) The earlier discussion of tanks as CAS targets still stands, but since the tank is the potential target requiring the highest degree of accuracy for a kill, it is the target around which this discussion will be framed.

The question which must be asked in determining the applicability of laser guided muntions to CAS is: "what is the *price* for the increased accuracy that terminal laser guidance provides?" That price is exacted in two ways by laser guided munitions: first, in the delivery parameters required by laser guided munitions; and, second, by the increased demands that terminal guidance places on the quality and duration of laser designation.

First, the threat will be a significant factor in determining the weapon delivery parameters which can be achieved without unduly compromising the survivability of the delivery aircraft. In any combat environment which has a Soviet style integrated air defense system (IADS), "Vietnam style" CAS, where the delivery aircraft could loiter in the target area with impunity and conduct unlimited two way radio communication with the FAC, will not work. (17:28) In the first four days of the 1973 war, operating against such an IADS, the Israelis lost 18% of their tactical air force. (19:32) The Soviet mobile tactical SAM air defense of the battlefield provides coverage up to 30 thousand meters in altitude and out to 95 thousand meters in range (22:74), making it impossible to release a "non-powered" weapon above, or horizontally outside the threat envelope. That threat dictates that the CAS aircraft take advantage of the relative sanctity of low altitude and employ a low angle pop-up attack for target acquisition to minimize its exposure to the threat during weapon delivery. (17:32) The low altitude pop-up attack thus driven by the threat requires a retarded weapon to enable safe delivery, and is therefore not compatible with LGB's since they are not retarded. Because of the practical time requirements driven by the "lock on before launch" characteristic of the Laser Maverick, it also is not compatible with this tactic. The Laser Maverick is a missile and, therefore, has significantly increased range derived from its rocket propulsion.

Its guidance system has the capability to acquire a properly designated target out to eight thousand meters. These characteristics will enable Laser Maverick to be employed using a relatively "*safe*" low level, long range release, as long as line-of-sight exists from the delivery aircraft to the target. (1:39,40) As we will see in a moment, however, even though the delivery parameters can possibly be met without unduly compromising the survivability of the delivery aircraft by employing Laser Maverick, a further difficulty arises from the extensive duration of laser designation required by this tactic.

The second way that laser guided munitions extract their *price* is in the requirement for laser designation of relatively high quality and long duration. A case can be made that this requirement, by itself, limits the usefulness of laser guided weapons in all but the most permissive environment, similar to that experienced in Vietnam. We have already seen how the IADS precludes achieving the delivery parameters of an LGB, but in addition to that limitation, the requirement for a "period" of guided flight make it even more difficult to attain the acceptable delivery parameters for a LGB in any but the most permissive environment. As was pointed out earlier, the Laser Maverick (lock on before launch) requires continuous laser designation for some finite period before missile launch (the pilot must acquire the target), and then for the entire flight of the missile (it will "fly up and away" if it detects a malfunction or the loss of

reflected laser energy}. {1:39,40} An additional period of designation must be added to allow time for the "coordination lag"; that period of time that the the target must be designated early to ensure that it is being designated at the right time. That coordination lag will increase as the enemy inhibits the ability of the designator operator and delivery aircrew to communicate with each other. This additive combination of designation requirements results in a relatively long mandatory period of continuous designation, especially if the missle is delivered at the outer limits of its range envelope, as discussed above. As pointed out in the Marine handbook on laser designators,

> "...the Soviet Union and its Warsaw Pact allies are equipped to detect and counter the increasingly sophisticated and effective guidance systems used in precision guided munitionsd. They have long recognized that there are relatively inexpensive, but very effective, laser countermeasures available in the form of natural and man-made obscurants which significantly degrade laser-guided weapon systems...because of the significant threat posed to enemy armor and other high vialue targets by laser-guided munitions, it can be expected that ground-based laser designators will become priority targets..." {10:1-2}

The additive combination of designation requirements discussed above results in an extensive mandatory period of continuous designation during which the enemy can employ laser countermeasures, or fire on the laser designator. It should be pointed out however, that the difficulties cited above are dramatically reduced, if the threat will allow freedom of

maneuver to the delivery aircraft and the designator, and unimpeded two way communications.

3. Nonterminal guidance uses for lasers. This paragraph will discuss the potential uses of lasers on the CAS battlefield other than the terminal guidance of laser guided weapons. These potential uses nearly all rely on the designator being able to transmit coded laser energy and the aircraft LST being able to receive that energy. The single addition to that usage is the employment of the MULE to determine range and azimuth, as in the conduct of a RABFAC mission.

The risk associated with the target detecting the lasing and the difficulty of the designation task are both dramatically reduced through this application. There is no lengthy period of required designation for terminal guidance, and a spot near a visually identifiable target can be as effective as a spot on the target because the pilot may then be able to visually acquire the target. This "offset lasing" nearly eliminates the possibility that the target can "sense" that it is being lased.

Although coordination is still necessary to assure that the receiver and the designator are set on the proper code and that the designator is on at the proper time, the existing system and procedures for coordinating the mark on target at the proper time will suffice.

Another function that the properly coded laser spot on the

target could fill is the transmission of the vital "clearance to drop". In this application, by prearrangement, if the pilot "sees" the properly coded spot, he knows it marks the target, and that he is cleared to drop without any other form of communication. Conversely, in the absence of the properly coded spot, clearance to drop is not conveyed and must be received in another manner. The same method of coordination could be used to designate other items of importance such as control points and friendly locations (with a diffused laser designator). The final role that the MULE can fill is in the conduct of RABFAC missions as discussed earlier.

4. Alternatives to laser guided weapons. It is axiomatic that a terminally guided weapon will have consistently better accuracy on a properly designated target than will an unguided weapon. That accuracy advantage has diminished significantly, however, since the days of the Vietnam conflict. The A-4 and F-4 using the then current delivery systems were credited with an accuracy of 20-40 mils for the A-4 and twenty mils for the F-4. The current delivery system in the A-4 and AV-8B, the Angle Rate Bombing System (ARBS), is credited with seven mil accuracy and the F-18 is expected to have the same degree of accuracy in the air-to-ground mode (5:38). The miss distance when a retarded MK-82 GP bomb is released in a ten degree dive at 500 feet AGL with a slant range of approximately 2500 feet should be approximately

18.5 feet with a "seven mil" system compared to fifty feet for a "twenty mil" system and 100 feet for a "forty mil" system. The above example is for a "minimum range release", and the miss distances will increase proportionatley as the slant range is increased. This accuracy is predicated on a clearly identifiable target, but by using the laser designator and LST to mark the target, the target can be clearly and unambiguously depicted, day or night.

5. Conclusion. There is a suitable application for lasers on the CAS battlefield, but it is not the terminal guidance of laser guided weapons. The gains in accuracy accomplished by employing terminally guided weapons on the CAS battlefield are more than offset by the difficulties and hazards associated with providing the required long duration and flawless designation on the target, as well as achieving the delivery parameters for those weapons. That becomes even more evident when one considers the ground based weapons available in the "defense in depth" concept that have the requisite accuracy and lethality to destroy, or disable tanks; the predominate target on the CAS battlefield requiring the "direct hit" that terminal guidance can provide.

The primary application for which lasers are suited is that of designating targets and communicating other information to the aircrew of CAS delivery aircraft equipped with laser receivers.

In that role, lasers provide significant improvements in the coordination of CAS missions with the ground maneuver element and in target marking. The improvements that have been made in the accuracy of aircraft weapons delivery systems, especially on targets whose exact location have been pointed out by a laser designator, have obviated the need for terminally guided weapons except for extremely hard targets like tanks. In special scenarios where the threat will allow, and the targets warrant, laser guided weapons remain an option, but must not be considered as a likely choice in most cases.

The USMC should continue to examine and invest in current and evolutionary laser designators and receivers, but should not invest further in LGB's or Laser Mavericks for employment in CAS.

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